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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM

FOR THE

UNIVERSITY OF CALIFORNIA MEETING

AT

BERKELEY, CALIFORNIA

DECEMBER 22–23, 1939

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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

BERKELEY MEETING, DECEMBER 22–23, 1939

THE 231st regular meeting of the American Physical Society will be held in Le Conte Hall at the University of California, Berkeley, California, on December 22–23, 1939.

Sessions for the presentation of ten-minute contributions will be held in Room 212 at 9:30 Friday and Saturday mornings and at 1:30 Friday afternoon. Members and others in attendance will be enabled to take luncheon together on Friday. The new 60-inch cyclotron will be available for inspection.

Columbus Meeting. The preliminary arrangements for the Columbus program include a joint session on Friday afternoon, December 29, with Section B—Physics of the American Association for the Advancement of Science and the American Association of Physics Teachers. Dr. Herbert E. Ives of the Bell Telephone Laboratories, Retiring Vice President for Section B, will deliver an address entitled "The Measurement of Velocity with Atomic Clocks." Professor I. I. Rabi of Columbia University will address the session on the subject "Radiofrequency Spectra of Atoms and Molecules." The presiding officer will be the Vice President of Section B, Professor E. O. Lawrence of the University of California. There will also be a joint dinner with the American Association of Physics Teachers on Friday evening, December 29.

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

On December 28, 1936, the Society voted that:

> No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

DEC 8 1939

Other meetings for the current season are as follows:

232. December 28–30, 1939. Columbus, Ohio. Annual Meeting.

233. February 22–24, 1940. New York, N. Y. Joint meeting with the Optical Society of America.

234. April 25–27, 1940. Washington, D. C.

235. June, 1940. Pacific Coast.

236. June 28–29, 1940. State College, Pennsylvania.

PAUL KIRKPATRICK
Local Secretary for the Pacific Coast
Stanford University, California.

December 6, 1939.

PROGRAM

FRIDAY MORNING AT 9:30 O'CLOCK

Room 212

1. A Theory of Spark Discharge. J. M. MEEK, *University of California. (Introduced by Leonard B. Loeb.)*—The breakdown of a gas in a uniform field proceeds by the transition of an electron avalanche into a positive streamer which develops in the direction of the cathode to form a conducting filament bridging the gap. Such a transition probably occurs when the radial field about the positive space-charge in an electron avalanche reaches a value of the order of the external applied field. Photoelectrons in the immediate neighborhood of the avalanche will thus be attracted towards it and a self-propagating positive space-charge streamer forms. This theory is based on ionzation by electrons and photo-ionization in the gas, and is independent of the classical assumption of ionization by positive ions in the gas or at the cathode. The theory yields an equation for the calculation of the sparking potential which can be solved by reference to $\alpha/p - X/p$ curves. The equation deviates slightly from Paschen's Law as it depends on ion densities instead of the total number of ions. Satisfactory agreement between calculation and experiment is obtained in air for values of pressure times gap length down to $p\delta \sim 100$ mm Hg×cm. Ion densities in sparking fields for $p\delta < 100$ are insufficient for streamer formation and breakdown proceeds by secondary electron liberation at the cathode in conformity with observation.

2. Optical Properties of Evaporated Silver Films. JOHN STRONG AND BARRY DIBBLE, *California Institute of Technology.*—Reflectivity, R, and transmissivity, T, have been measured for 200 silver films. The measured values when plotted against surface density exhibit "erratic" deviations from a smooth curve. However, plotting R *versus* T yields a consistent and reproducible but discontinuous curve having two branches. One branch connects continuously with the R of bulk silver, while the other connects continuously with the point representing the bare backing glass. The two branches define two apparently *distinct physical states:* α-type silver films continuous to the opaque films and β-type films continuous to the thinnest film. Properties of the films are as follows: α-type films have a high efficiency $(R+T)$ and exhibit little or no scattering. β-type films have a low efficiency, scatter red light and have a transmission minimum at a wave-length which is proportional to the surface density.

Thin films deposited on a glass plate by backward scattering of evaporated silver give values of R and T which fall on the branch of the curve characterizing β-type films. Furthermore, thicker deposits obtained in this manner give points which extend the branch toward opaque films.

The sputtered films of Goos[1] are best represented by the extended branch of the β-type films.

[1] F. Goos, Zeits. f. Physik **100**, 95 (1936).

3. Absorption Spectra of Certain Diatomic Halides. CHARLES A. FOWLER, JR. AND F. A. JENKINS, *University of California.*—A systematic search for new band systems in the absorption spectra of certain diatomic halides has been carried out in the wave-length region 1950 to 7500A. The salts were vaporized at temperatures between 900 and 2200°C in a carbon-tube furnace previously described.[1] Band systems located under low dispersion were photographed in the first order of the 21-foot grating (average dispersion 1.3A./mm). A further ultraviolet system of BeF was not observed, but high dispersion spectrograms of the $1,0\ ^2\Pi - ^2\Sigma$ band in absorption afforded a very sensitive test for the once reported[2] but doubtful isotope Be^8. The plates show no band head due to Be^8F. The analyses of new band systems of the fluorides of Mg, Ca, Sr, and Ba have given vibrational constants and electronic energies of twelve hitherto unknown electronic states. New band spectra of CdF and SnCl have been photographed and analyzed. Of the fluorides of the iron group, only CoF produced a band spectrum within the limits of observation.

[1] F. A. Jenkins and George D. Rochester, Phys. Rev. **52**, 1135 (1937).
[2] W. W. Watson and A. E. Parker, Phys. Rev. **37**, 167 (1931).

4. On the Mechanism of Boundary Lubrication. Part I. Wear Prevention by Addition Agents. J. W. GIVENS, OTTO BEECK AND E. C. WILLIAMS, *Shell Development Company, Emeryville, California.*—If two metal surfaces slide over each other in the presence of a lubricant and under high load, high pressures and temperatures prevail at those isolated spots which actually carry the load, leading to wear and possibly to breakdown. The action of wear preventing agents has been studied. Such agents are effective through their chemical polishing action, by which the load is distributed over a larger surface and local pressures and temperatures are decreased. Especially effective are compounds containing phosphorus or other elements of Group V of the periodic system. These have been found to form a metal phosphide or homolog on the surface which is able to alloy with the metal surface, lowering its melting point markedly. The wear experiments were carried out with a highly sensitive and accurate method which uses metal-plated steel balls as its sliding elements. Under the experimental conditions additions of 1.5 percent triphenyl phosphine or triphenyl arsine in white oil gave wear prevention factors of 7.2 and 12.2, respectively (relative to pure white oil). A further addition of 1 percent of a long chain polar compound is able to double the wear prevention factor obtained with the polishing agents and wear prevention factors as high as 17.6 have been observed.

5. On the Mechanism of Boundary Lubrication. Part II. The Action of Long Chain Polar Compounds. OTTO BEECK, J. W. GIVENS AND A. E. SMITH, *Shell Development Company, Emeryville, California.*—Coefficients of kinetic friction for

many oils were measured and the structure of thin films of the oils rubbed on polished mild steel surfaces was investigated by electron diffraction. Oils showing no or little surface orientation had a constant coefficient of friction of about 0.1 over the available velocity range from 0 to 1 cm/sec. With oils which showed high surface orientation imparted by addition of long chain polar compounds, a sudden decrease of the coefficient of the friction by a factor of about 10 was observed at various velocities of the sliding surfaces, depending upon the compound used. Those compounds causing the effect to occur at the lowest velocities were found to be most highly oriented with their carbon chains most nearly perpendicular to the surface. Such a change of the coefficient of friction can be explained only by the wedging of oil under the surface (oil drag), leading to a type of "quasi-hydrodynamic" lubrication. The regions of sudden decrease of the coefficient of friction correspond to a change from metallic contact to extremely high electrical resistance. The investigation shows that long chain polar compounds act primarily by inducing the "wedging effect" and not by giving a direct protection to the surface.

6. Theory of Composition of Bearing Alloys. S. KYROPOULOS, *California Institute of Technology.*—From structure and running properties of Babbitt metals engineering derived rules for the development of bearing alloys. Conventional theory considers a hard structural element, embedded in a soft matrix metal, the fundamental requirement for a bearing metal. The hard constituent is interpreted as the actual carrier of the normal journal load, the soft matrix as its yielding support above which the hard constituent stands in relief. In thin film lubrication the soft "valleys" are believed to retain oil. The theory offers no explanation for the performance of certain pure metals. It is shown that the metals used in practice for soft matrices—and only these—have outstandingly high thermal expansion. Thus, under critical operating conditions it is the soft constituent in a good bearing that carries the load. Stress analysis in the case Cu-Pb yields for coherent Cu-structure load carrying capacities of the order found in practice and its variations with structure in agreement with experience, the strength of the Cu adding itself to the strength of the Pb. The conception includes the case of pure metals as a limiting case and explains their individual behavior.

7. Radioactive Hydrogen. L. W. ALVAREZ AND R. CORNOG, *Radiation Laboratory, University of California.*—Further tests have confirmed our suggestion[1] that H^3 produced in the D−D reaction is radioactive. We have bombarded heavy water with deuterons and observed the concentration of the radioactive hydrogen in electrolysis. This, together with the fact that no activity can be detected in the electrolytic oxygen, indicates that radioactive body must be a heavy isotope of hydrogen. The yield of active atoms, as determined by Geiger counter experiments, is about equal to the number of neutrons produced in the D−D reaction, lending support to the assignment of mass 3. The half-life is being measured on three samples, one of which has been followed for 80 days; the best value at present is 230±50 days. The average energy of the beta-rays has been estimated from the ratio of the number of active atoms to the number of ion pairs formed in a given volume of gas, and independently from range measurements. These rough measurements both give about 10 kev. A precision measurement by electrostatic methods is now in progress.

[1] L. W. Alvarez and R. Cornog, Phys. Rev. **56**, 613 (1939).

8. D. C. Amplifier. W. M. BRUBAKER, *Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.*—A method of directly coupling successive stages of a vacuum-tube amplifier without the use of batteries has been devised. The efficiency of the coupling is constant for audio or zero frequency, and may easily be made as high as 80 percent. The cathodes of all stages are at the same potential. Thus, with the aid of gaseous discharge voltage regulator tubes, all stages may be operated from a common power supply. Negative feedback, with all of its advantages, is easily incorporated. Degenerative feedback aids the stability of the amplifier so that it may be operated directly from alternating current.

9. The Measurement of Gamma-Ray Energies. A. C. HELMHOLZ, *Radiation Laboratory, University of California.*—A magnetic spectrograph using photographic film as a detector has been used to investigate some γ-rays. In Ga^{67}, the K and L conversion lines of the γ-ray reported by Alvarez[1] have been measured. The energy is 93 kv, in good agreement with the work of Valley and McCreary.[2] K photoelectrons ejected from tin by the same γ-ray have also been photographed. This confirms Alvarez's result that the γ-ray is only partially converted. In addition photoelectrons ejected from gold and from tin by a 182-kv γ-ray have been observed. The one-hour Se, reported by Langsdorf and Segrè[3] as an isomeric transition in Se^{79} or Se^{81}, was found to give two lines corresponding to the K and L conversion of a 93-kv γ-ray. Successive exposures showed these lines to be due to a substance with the appropriate half-life. The isomeric transition of half-life 52 hours found by Walke[4] in Sc^{44} gave a line of electrons at about 260 kv, which is in agreement with his absorption measurements of the energy. Two samples of long-lived radioactive element 43 formed by deuteron bombardment of molybdenum, one aged one year, the other about eight months (both were kindly prepared by Dr. E. Segrè), gave two lines corresponding to the K and L conversion of a 97-kv γ-ray.

[1] L. W. Alvarez, Phys. Rev. **54**, 486 (1938).
[2] G. E. Valley and R. L. McCreary, Phys. Rev. **56**, 863 (1939).
[3] A. Langsdorf and E. Segrè, Phys. Rev. in press.
[4] H. Walke, Phys. Rev. in press.

10. Internal Scattering of Gamma-Rays. E. P. COOPER AND P. MORRISON, *University of California. (Introduced by J. R. Oppenheimer.)*—If an element is irradiated with gamma-rays of sufficiently high energy, the upper limit of the Compton recoils is less than the minimum energy of photo- or conversion electrons from any shell. But electrons of energy between these two limits may be ejected in processes in which the momentum condition can be relaxed.

Such processes are (1) the scattering of an external gamma-ray by a bound electron, where momentum can be taken up by the nucleus, (2) the internal scattering by the electrons of the radioactive atom itself, where the radiation field of the near-by nucleus can fulfill momentum conditions impossible for a plane wave. We consider the second case, for scattering of an electric dipole gamma-ray by s electrons. We use Dirac electron theory with Born approximation. The process is of order α compared to the internal conversion, as expected. Our small result indicates that most of the electrons observed in such a region—for instance from the 2.62 Mev gamma-ray of Th C″—are of instrumental origin. This is in agreement with the results of Alichanian and Nikitin.*

* A. Alichanian and S. Nikitin, Comptes rendus de l'Acad. des Sciences U.S.S.R. **19**, 337 (1938).

11. Air Mass Effect on Cosmic-Ray Intensity. DONALD H. LOUGHRIDGE AND PAUL GAST, *University of Washington.*—Blackett[1] has suggested that the "temperature effect" of the cosmic rays is due to the vertical shift of the layer in which the mesotrons are formed and has further suggested that it may be possible to correlate cosmic-ray data with the structure of depressions. Data obtained with a Carnegie, Model C cosmic-ray meter loaned to us by A. H. Compton indicate a noticeable change in intensity at the fronts separating different air masses. The data were obtained while the meter was on board the *M. S. Northland* traveling between Seattle and Juneau, Alaska, in the process of investigating the latitude effect. The location of the fronts was obtained from the Seattle airport office of the U. S. Weather Bureau. Of the twelve fronts investigated, three were cold fronts, one was warm, and eight were occlusions. The cold fronts gave changes of from 2.9 percent to 5 percent; the warm front gave a change of 2 percent, while the occlusions gave changes of from 1.7 percent to 2.5 percent. The changes took place over a space of from one to three hours. Two further cases of fluctuation were noticed, one accompanying an influx of warm moist air aloft, the other representing a zone of transition which contained no definite front.

[1] P. M. S. Blackett, Phys. Rev. **54**, 973 (1938).

FRIDAY AFTERNOON AT 1:30 O'CLOCK

Room 212

12. Back Diffusion in Oil Vapor Vacuum Pumps. R. CORNOG, *Radiation Laboratory, University of California.*—The new 60-inch cyclotron is at present evacuated with the aid of an oil vapor diffusion pump with a pumping speed of about 3000 liters per second. In connection with the design of this pump, experiments were performed which showed that as the backing pressure on the high pressure side of a single, pumping, oil jet is increased, the amount of gas diffusing back against the jet of oil vapor increases linearly with the pressure until a certain critical pressure is reached. The slope of this curve varies widely with the physical proportions of the pump. At the critical pressure, the pumping action of the jet breaks down completely, and gusts of gas blow continuously back through the jet.

13. Levels of Emission of Night-Sky Spectra. J. KAPLAN, *University of California at Los Angeles.*—This discussion regarding the amounts of atomic oxygen and nitrogen in the upper atmosphere, and the heights of origin of the green auroral line and the atomic nitrogen lines $^4S-^2D$ in the night sky, is based on their transition probabilities and on recent laboratory and field observations. According to Pasternack, the transition probability of the green auroral line is about 53,000 times that of the lines which originate on the ^2D level of nitrogen. The laboratory observation of this highly improbable transition and its probable presence in H. W. Babcock's night-sky spectra with an intensity 1/50 that of the green line, leads to two alternative conclusions. If both radiations originate in the same region of the atmosphere there must be about 1000 times as much atomic nitrogen present as atomic oxygen, provided the excited states are produced at equal rates. On the other hand, the auroral green line may be emitted high in the atmosphere and the nitrogen lines as low as the ozonosphere. The latter is in agreement with the recent observations of the enhancement of the nitrogen lines and the Vegard-Kaplan bands with pressure. It suggests that different mechanisms of excitation are responsible for the two radiations.

14. Night-Sky Light and Nocturnal E Layer Ionization. N. E. BRADBURY AND W. T. SUMERLIN, *Stanford University.*—In accordance with the suggestion that the sporadic nocturnal E layer ionization may be associated with variations in the luminosity of the night sky, a simultaneous investigation of both these phenomena has been carried out. The intensity of night-sky light was determined by means of a recording electrometer and photoelectric cell, measurements being made only after twilight and during such times as the moon was below the horizon. At different times both a Kunz KH cell and a CeO cell were employed. The ionosphere was investigated simultaneously using a pulse transmitter and photographically recording receiver operating at a frequency of 2.1 megacycles. The blue portion of the night-sky luminosity appears to increase after sunset to a maximum shortly after midnight with a subsequent slow fading. The light in the red region of the spectrum shows much greater fluctuations in intensity and is brightest after sunset and decreases continuously thereafter. Practically no correlation has been found between the intensity of the night-sky light and the character of the

ionospheric reflection. Various possibilities may be suggested to explain this result.

15. Artificially Produced Alpha-Particle Emitters. DALE R. CORSON AND KENNETH R. MACKENZIE, *Radiation Laboratory, University of California.*—By bombarding heavy elements with the 32-Mev alpha-particles available with the 60-inch cyclotron, we have produced radioactive substances which decay by alpha-particle emission. Lead and bismuth in particular emit appreciable numbers of alpha-particles after bombardment. We have done some preliminary experiments on bismuth to determine the nature of the radioactive processes. We have observed two alpha-particle periods: one of half-life 7.5 hours and one of the order of months. The latter may possibly be due to RaF produced by deuteron contamination in the alpha-particle beam. Associated with the 7.5 hour period are two groups of alpha-particles, of ranges approximately 4.5 cm and 6.5 cm. Both groups are present in as nearly equal numbers as can be measured. We have sought to establish a genetic relationship between the two groups but with no success as yet. Several beta-ray periods are also present, but some of these are probably due to contaminations. Chemical identification of the radioactive elements is uncertain at present.

16. Some Effects of Disintegration Products, from the Reaction $_5B^{10}$+slow $_0n^1$, on Mammary Carcinoma, Lymphoma and Sarcoma. P. GERALD KRUGER, *Radiation Laboratory, University of California.*—Small pieces of mammary carcinoma, lymphoma, and an undifferentiated sarcoma have been immersed in a solution of boric acid and irradiated with slow neutrons before implantation. In this way the boron is disintegrated in the environment of the malignant cells and the disintegration products (Li^7 and He^4) produce intense ionization in the cells. All malignant tissues used were known to give 100 percent takes for normal unirradiated implants. Provisional results show that it is possible to kill the irradiated bodies when the fast neutron γ-ray background is approximately one-fifth of the dose which will allow 100 percent takes (i.e., sub-lethal dose) in mammary carcinoma. At the same time the boron controls of seven experiments averaged better than 90 percent takes. This method has the distinct advantage of localizing the lethal ionization in the region where the boron disintegration takes place and thus removes (in the case of its application to *in vivo* work) the danger of skin burns and similar disturbing factors which are prevalent in x-ray and neutron therapy. Thus, it seems that this boron slow neutron method may develop and be applicable to the treatment of malignant growths *in vivo*. Experiments to test such applicability are now in progress.

17. Graphical Representation of Relations between e, m and h. RAYMOND T. BIRGE, *University of California.*—R. A. Beth[1] and J. W. M. DuMond[2] have presented three-dimensional plots designed to represent observed values of various functions of e, m and h. By taking a properly chosen cross section of such a plot, one obtains the relations between some two independent variables, each of which is a $f(e, m, h)$. Such a two-dimensional plot of some arbitrarily chosen pair of independent variables may, however, be constructed without reference to any postulated three-dimensional origin. In fact, such reference often introduces, in this case, an entirely unnecessary complication. Two general types of two-dimensional diagram are now in use, (1) an ordinary type of plot, using rectangular or oblique coordinates, (2) a parallel line nomographic chart. There are an indefinitely large number of possible varieties of each type, and for any one variety of one type there is always a precisely corresponding representative of the other type. The purpose of this paper is to present entirely general but very simple equations, which represent explicit directions for the construction of each of these types of chart, for any assumed pair of independent variables. All two-dimensional plots previously used constitute merely certain special cases of these general equations.

[1] R. A. Beth, Phys. Rev. **53**, 681 (1938); **54**, 865 (1938); **56**, 208 (1939).
[2] J. W. M. DuMond, Phys. Rev. **56**, 153 (1939).

18. Calculation of the Efficiency of a Condensing Surface as a Function of the Observed Yield. JOSEPH SLEPIAN AND W. M. BRUBAKER, *Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.*—The kinetic theory of gases gives the number of molecules crossing from one side to the other of a unit surface in unit time in a gas in equilibrium as $\frac{1}{4}N\bar{c}$, where N is the molecular density and $\bar{c}$ the mean velocity of thermal motion. The number of molecules striking the wall of a vessel containing the gas or vapor is given by the same expression if the molecules are reflected from the surface. However, if the gas consists entirely of a condensable vapor and the surface condenses perfectly, the vapor will be in a state of flow and the number of molecules striking the surface may be computed from the mathematical theory of the mechanics of continuous fluids. For surfaces which condense only a part of the incident molecules, a combination of these two methods may be used to determine the number of molecules which strike the surface in terms of the number removed by condensation. This procedure is outlined and the results shown by a curve.

19. Spinor Wave Equations Linear in the Momentum. L. I. SCHIFF, *University of California.*—Relativistic wave equations, to be physically satisfactory, should be derivable by means of a variational principle from a Lagrangian that is invariant under Lorentz transformations, invariant under mirroring of the space coordinates, invariant under gauge transformations, and real. We consider here the construction of spinor Lagrangians that give wave equations that are linear in the wave fields, the momentum operator, and the electromagnetic potential, such that all spinors provide irreducible representations of the Lorentz group. We further impose the physically plausible requirements that in the absence of an electromagnetic field the spinors provide an irreducible representation of the space rotation group and each component satisfies the Klein-Gordon equation. It is then possible to construct one, and in general only one, satisfactory Lagrangian for any value of the spin, without introducing supplementary fields. For a particle of spin $\frac{1}{2}$ there exists one other Lagrangian,

involving supplementary fields, that meets all of the above requirements. It seems likely that such Lagrangians involving supplementary fields exist in general.

20. On the Energy Levels of Particles without Spin. H. SNYDER AND J. WEINBERG, *University of California. (Introduced by J. R. Oppenheimer.)*—In the presence of an electrostatic field (but not for a static world scalar or magnetostatic field) the stationary solutions of the quadratic relativistic wave equation for scalar particles do not form an orthonormal set. In spite of this they may in general be used to introduce normal coordinates for the quantum theory of this field. For if the wave function and its canonical conjugate are expanded in the usual way in terms of these stationary solutions u_k (with characteristic energies E_k), then it may be shown that the amplitudes a_k in this expansion satisfy the commutation rules

$$[a_k, \bar{a}_l]=\delta_{kl}/\epsilon_k \quad \text{with} \quad \begin{matrix}(E_k-V)^2u_k=(m^2c^4-\hbar^2c^2\Delta)u_k, \\ \epsilon_k=2\int |u_k|^2 d\tau(E_k-V),\end{matrix}$$

which follow from the wave field commutators and the assumption of the integrability of the classical wave equation for arbitrary initial function and time derivative. Total energy and total charge then take on the characteristic values

$$E=\sum_k (N_k+\tfrac{1}{2})\frac{\epsilon_k E_k}{|\epsilon_k|}\,; \quad e=\sum_k N_k \frac{\epsilon_k}{|\epsilon_k|}$$

with integral N_k's. The case where ϵ_k vanishes corresponds to the Klein paradox, to pair creation by static fields; it requires special consideration. This case cannot occur for a Coulomb field, $z<137$.

21. Shielding of High Energy Neutrons by Water Tanks. S. M. DANCOFF, *University of California. (Introduced by J. R. Oppenheimer.)*—Estimates are made here of the thickness of a water tank surrounding a neutron source such as a cyclotron necessary to reduce the number of neutrons by any given factor. For the diffusion through hydrogen alone it is possible to set up a diffusion equation which describes approximately the energy distribution of neutrons emerging from a given thickness of material. When the effect of the oxygen atoms in water is included, the complete distribution can no longer be obtained from the approximate differential equation, but estimates good to within a few inches may be made of the tank thickness required to accomplish the desired reduction. Here we consider only the reduction in the number of neutrons above a volt. Neutrons below a volt are known to diffuse only a few centimeters in water before being captured by protons. For an initial homogeneous neutron beam of energy 10 Mv, it is found that 5 ft. of water will reduce the number of neutrons to 10^{-5} the initial number. The same thickness of water tank, however, will absorb only 10^{-3} the number of γ-rays formed in the tank in the capture of the slow neutrons.

22. Deflection Measurements by Mechanical Interferometry. R. WELLER, *Washington State College.*—One may measure deflection at all points in a 2-dimensional stress system in a single operation by using the interference fringes resulting from the superposition of two screens, one of which is attached to the part under load and the other placed over the first as a reference. The screens consist simply of square cross-hatching, one attached directly to the model or photographed onto it, the other on a transparent base, such as a photographic plate. If the screens are identical, they will form no interference patterns when superimposed, but when one is deformed by being attached to a loaded model, interference between the screens produces fringes resembling those formed in photoelastic experiments but for a mechanical rather than an optical reason. Two families are observed, the fringe order in each family giving the deflection corresponding to a single coordinate direction. Thus square screens will give the X and Y coordinates of deflection at each point, polar screens the R, θ coordinates, etc. The usefulness of the method is not limited to systems operating below the elastic limit, but is applicable to mixed deflection, that is, wherein part of the deflection is elastic and part plastic.

23. Onset and Corona Studies with Confocal Paraboloids in Air at Atmospheric Pressure. K. E. FITZSIMMONS, *University of California and Washington State College. (Introduced by Leonard B. Loeb.)*—Oscillographic observations have been made on the discharge between confocal paraboloids in dry and moist air at atmospheric pressure. A positive point was used. Accurate solutions of fields before corona onset can be made. In dry air, streamers occurred before "bursts" for the case of short gaps. With longer gaps it is difficult to distinguish between bursts and streamer pulses in the pre-onset region. With moist air, for all gaps observed, burst pulses occur before streamers. At voltages similar to those for onset of steady burst corona in dry air the oscillograph shows a rapid succession of very intense streamers. Current measurements at these potentials show a comparatively large rather unsteady current which drops rapidly to a certain minimum as voltage increases. At this point of minimum current the streamers disappear and there is steady burst corona. Further increase in voltage then gives a current increase. Breakdown streamers were not observed with any gap used for either dry or moist air.

24. An Exact Solution of the Boltzmann Equation Applicable to the Diffusion of Neutrons. E. A. UEHLING AND E. A. SCHUCHARD, *University of Washington.*—An exact solution of the Boltzmann equation describing the distribution function $f(\vec{r}, \vec{v}, t)$ of an absorbable particle diffusing in a half-infinite homogenous medium has been obtained subject to the following restrictions: (1) steady-state conditions, (2) continuous distribution of sources which emit isotropically and depend in strength on the distance x from the boundary plane like e^{-mx}, $m \geqslant 0$, $x \geqslant 0$, (3) isotropic scattering of the diffusing particle in the medium without energy exchange. These restrictions reduce the distribution function to $f(x, \zeta)$, where $\zeta = \cos\theta$, and θ is the angle between the velocity vector and the x direction. Considering the function $f(0, \zeta)$, $\zeta < 0$, and its analytic continuation over the complex ζ-plane, one obtains an integral equation which has the same form as that fitted to the boundary conditions of vanishing sources and an incident current at $\zeta_0 \sim 1/m$ $(0 \leq m \leq \infty)$. Thus, the problem of such sources is reduced essentially to that of Halpern, Lueneburg and Clark.[1] The emerging currents corresponding to $f(0, \zeta)$ for $m = 0$, with the ratio of scattering to capture cross section equal to 0, 150 and ∞, respectively, are compared with Fermi's law, $-\cos\theta(1 - \sqrt{3}\cos\theta)$, and with the experimental results of Hoffmann and Livingston[2] for thermal neutrons emerging from paraffin.

[1] Halpern, Lueneburg and Clark, Phys. Rev. **53**, 173–83 (1938).
[2] Hoffmann and Livingston, Phys. Rev. **53**, 1020–1 (1938).

25. On the Theory of the Oppenheimer-Phillips Process. G. M. VOLKOFF, *University of California.*—A critical study of the previous theoretical treatments[1] of the process of neutron capture by heavy nuclei bombarded with low energy deuterons shows that while the dependence of the transmutation function on the incident deuteron energy has been given correctly, the energy distribution of the outgoing protons has not been satisfactorily estimated. A reinterpretation of Lifshitz' result shows that his expression for the energy distribution is closely related to the deuteron wave function, but does not directly give the proton energy distribution. It is found that a justification may be given for the methods employed by Bethe in setting up the expression for the proton energy distribution as a product of two factors: the "sticking probability" of the neutron, and the penetrability of the potential barrier, but our evaluation of the latter factor yields a result differing from Bethe's. The asymptotic behavior of this second factor for high proton energies is found to be $E^{-7/2}$ instead of $E^{-3/2}$ as given by Bethe. At intermediate values of E it has a maximum, and for $E \to 0$ it behaves like $\exp(-2\pi n)$, where $n = Ze^2/\hbar v \sim E^{-\frac{1}{2}}$. The behavior of this factor for intermediate values of E is determined by the character of the deuteron wave function and may be found numerically for particular cases.

[1] J. R. Oppenheimer and M. Phillips, Phys. Rev. **48**, 500 (1935). P. L. Kapur, Proc. Roy. Soc. **A163**, 553 (1937). E. Lifshitz, Phys. Zeits. d. Sowjetunion **13**, 224 (1938). H. A. Bethe, Phys. Rev. **53**, 39 (1938).

26. Probe Measurements in Point-to-Plane Corona Discharge in Air. V. B. WAITHMAN AND W. R. BAKER, *University of California. (Introduced by Leonard B. Loeb.)*—In an attempt to analyze the spark breakdown with negative point-to-plane corona it appeared likely that breakdown occurred when the negative ion space charge gradients at the anode reached such values as to lead to positive streamer formation. These streamers effecting junction with the glow discharge-like region about the point lead to a spark. This supposition necessitated for its verification space potential measurements away from the point and near the plate. To this end various probes were developed and tested on the positive point corona where conditions are simple. Both plane and point probes were used on corona gaps of 4–6 cm with points of 0.2 mm diameter in room air and dried air at low currents and at currents just below breakdown streamer onset. The potentials observed appear to be reliable to at least 10 percent up to 7 mm from the plate and 10 mm from the point. They indicated that fields at the plate could reach streamer propagating magnitudes at the sparking potential.

27. Internal Conversion in the *L* Shell. ELDRED NELSON, *University of California. (Introduced by J. R. Oppenheimer.)*—The internal conversion coefficients for s and p electrons in the L shell have been calculated by following the method of Dancoff and Morrison.[1] The formulas obtained are non-relativistic, applicable for $Z < 50$ and gamma-ray energy $\ll mc^2$, and give the conversion of electric multipole radiation of any order. The total internal conversion in the L shell is about one-tenth of the conversion in the K shell. The ratio of the conversion coefficient for six p electrons to the conversion coefficient for two s electrons is given by $Z\alpha\varphi/(\nu)^{\frac{1}{2}}$ and is less than 10 percent. Here Z is the atomic number, α is the fine structure constant and ν is the gamma-ray energy divided by mc^2. φ is a slowly varying factor of the order of a few percent that depends upon the multipole order, the gamma-ray energy and the atomic number in a complicated manner.

[1] Dancoff and Morrison, Phys. Rev. **55**, 122 (1939).

28. Extreme Ultraviolet Absorption Spectrum of Nitrogen. F. A. JENKINS AND R. E. WORLEY, *University of California.*—The band spectrum of N_2 in the region 1000–800A has been studied in absorption. The complex band structure in this region represents transitions to a number of electronic states immediately below the first ionization limit at 125,670 cm^{-1}. Several faint bands above this limit are also observed. About seven short v' progressions consisting of from two to six bands are identified among the stronger bands in the region below the ionization limit. All of these have very low vibration frequencies ($\Delta G' \sim 750$–450 cm^{-1}) as compared to the normal state (2360 cm^{-1}), and it is probable that the 0,0 band is not observed in any of these band systems. A general decrease in the values of ΔG for the systems in going toward higher frequencies is observed, indicating that they belong to

series approaching as a limit an unstable state of N_2^+. Analysis of the rotational structure of some of the bands has been possible, by using the combination principle. The values of B' thus obtained are small, as expected from the instability of the states. For one of the strongest bands at 102,870 cm^{-1}, $B' = 1.36_5$ cm^{-1}. Values as small as 1.03 cm^{-1}, requiring an internuclear distance of nearly four times that in the normal state, are observed for some of the bands of highest frequency.

29. Hyperfine Structure of the Quadrupole Line 2815A of Hg II. S. MROZOWSKI, *Joseph Pilsudski University, Warsaw, Poland. (Introduced by F. A. Jenkins.)*—The structure of many lines of ionized mercury is investigated by means of apparatus of high resolving power. Most of them have been found to possess complex structure. The components of the lines 2815, 3984 and 2848A are measured and the structure analyzed in terms of isotopic shift and hyperfine structure. It is shown that in the case of a forbidden line of quadrupole character like the line 2815A the intensities of the hyperfine components must be computed using the formulas given by Rubinowicz (replacing J, L and S by F, J and I). The hyperfine structure splittings of the levels $6s^2S_{\frac{1}{2}}$, $5d^96s^2\ ^2D_{5/2}$ and $6p^2P_{3/2}$ found experimentally are in agreement with Goudsmit's formulas and allow in the case of the $6s^2S_{1/2}$ level a very accurate evaluation of the nuclear g factor for the isotope 199 ($g = 1.0944 \pm 0.0040$). The isotopic shifts in Hg II levels are discussed.

30. Spectrographic Determination of Vitamin A. MARTIN E. NELSON AND STANLEY S. BALLARD, *University of Hawaii.*—We have developed a simplified spectrographic method for determining vitamin A in oils, which is based on densitometric measurements of the absorption band at 3280A. Extinction coefficients for a one-percent solution in a one-centimeter cell were determined for the non-saponifiable fraction of the Reference Cod Liver Oil of the U. S. Pharmacopoeia, which is standardized to contain 3000 International Units of vitamin A per gram. The mean value of 21 determinations was 1.441 ± 0.019, with a standard deviation of 0.084 ± 0.013. This is in good agreement with the value 1.44 reported by Hume.[1] Three commercial cod liver oils, advertised to contain not less than 6000, 2000, and 1800 I. U. per gram, were assayed by comparison with the standard U. S. P. Reference Oil and found to contain 6170, 2600, and 1700 units, respectively. Absorption spectra were taken of extracts of opihi, the Hawaiian limpet, which had been assayed by feeding methods by Miller and Robbins[2] of the Hawaii Agricultural Experiment Station and found to possess, on the moisture-free basis, about one-tenth the vitamin A activity expected of a good cod liver oil. The vitamin A absorption band was not detected, but the characteristic absorption bands of β-carotene were prominent.

[1] E. M. Hume, Nature **143**, 22 (1939).
[2] C. D. Miller and R. C. Robbins, unpublished results.

31. The Onset of Positive Point-to-Plane Corona in Pure A, N_2, H_2 and in Dry Air at 350 mm Pressure. GERHARD L. WEISSLER, *University of California at Berkeley. (Introduced by Leonard B. Loeb.)*—The investigations of positive point-to-plane corona in air by G. W. Trichel[1] and Arthur F. Kip[2] indicated the necessity of a study of these coronas in free electron gases of different types. A study has been made by using a 2.5-cm gap with 0.4 mm diameter needle in the gases A, N_2 and H_2 of the highest purity in sealed off and outgassed tubes. The results in argon differed materially from the reported results in air, while those in N_2 showed an intermediate behavior. In A and N_2 avalanches could be observed at low potentials. At 300 volts below onset peculiar unresolved pulses like the Trichel burst pulses were observed in A. The main difference is that no streamers were observed in A. In N_2 the corona above onset resembled that in A. Pre-onset phenomena were analogous to air but well distinguished from it. Streamers were fewer and crossed the gap without breakdown, disappearing at onset. The results on the H_2 resemble those of the A. For the sake of comparability the same kind of investigation has been made on dry air in order to get the distinction in observations of the four different gases.

[1] G. W. Trichel, Phys. Rev. **55**, 382 (1939).
[2] Arthur F. Kip, Phys. Rev. **55**, 549 (1939).

32. The Absorption of Sound in Carbon Dioxide. ROBERT W. LEONARD, *University of California at Los Angeles. (Introduced by V. O. Knudsen.)*—The absorption of acoustical energy in carbon dioxide was measured by a direct method over a frequency range extending from 22 to 112 kc. The absorption coefficient was computed from photographic records of sound pressure as a function of distance from the source. The measurements were made in a chamber containing baffle plates which reduced the effect of reflection from the walls of the chamber. The results of a series of measurements on samples of carbon dioxide show that the frequency at which the absorption per wave-length is a maximum is as low as 30 kc in the purest sample measured. The average peak height from four sets of data was 0.251. From the peak position, the value for the average lifetime of a quantum of vibrational energy was computed to be $7.0\ 10^{-6}$ second. From the average peak height, it was necessary to assume that both the deformation vibration and the symmetrical valence vibration have relaxation times which are nearly identical, and further that the upper levels of the deformation mode be included in computing the vibrational specific heat producing the absorption peak.

33. Diffraction of Radio Ranges by Hills. WILLIAM R. HASELTINE, *University of California.*—The scattering of electromagnetic waves by hemispherical obstacles on a conducting plane has been investigated. The results have been applied to the problem of the splitting of radio range beacons when the range passes over hilly country. The calculations refer particularly to long wave-lengths (about 1000 meters) such as used in the Oakland range. It is found that even hills of moderate size can cause large spatial fluctuation in the received signal strength. In the cases where precise numerical calculations are practicable, the scattering masses are too symmetrically located to give rise to splitting of the range into parallel beams, but the large variations in intensity indicate that for less symmetrical situations this phenomenon would occur, and that the diffraction effects considered are the cause of the peculiar patterns actually found.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

The papers in the supplementary program may be called for only at the session indicated.

34. Nuclear Isotopic Shifts in the Band Spectra of HgH^+, HgD^+ and ZnH. S. MROZOWSKI, *Joseph Pilsudski University, Warsaw, Poland.*—The isotope effect in the lines of the band spectra of HgH^+, HgD^+ and ZnH is studied with spectral apparatus of high resolving power. Besides the shifts caused by differences in the reduced masses for different isotopes of the heavy atom, which obey the well-known equations of Mulliken and of Birge very closely because of the small mass differences, it is shown that there are shifts originating in differences of the electric fields surrounding the nuclei. For the 0,0 band of the transition $^2\Pi_i \rightarrow {}^2\Sigma$ in ZnH, this additional shift is found to be $+0.006$ cm^{-1} between the lines of the even isotopes of Zn (Zn^{66} relative to Zn^{64}). In the case of HgH^+ and HgD^+ shifts are found which depend on the vibrational energy, the largest shift, of about -0.043 cm^{-1}, occurring between the even Hg isotopes in the 0,0 band of HgD^+. The shifts decrease with increasing vibrational energy of both upper and lower states, changing sign for sufficiently high energies and probably tending in the limit of dissociation toward the isotope shift observed in the λ2815 line of Hg II ($+0.280$ cm^{-1} for Hg^{202} relative to Hg^{200}).

AUTHOR INDEX TO ABSTRACTS OF THE BERKELEY MEETING

Alvarez, L. W. and R. Cornog—No. 7

Baker, W. R.—see Waithman, V. B.
Ballard, Stanley S.—see Nelson, Martin E.
Beeck, O., J. W. Givens and A. E. Smith—No. 5
—— see Givens, J. W.
Birge, Raymond T.—No. 17
Bradbury, N. E. and W. T. Sumerlin—No. 14
Brubaker, W. M.—No. 8
Brubaker, W. M.—see Slepian, Joseph

Cooper, E. P. and P. Morrison—No. 10
Cornog, R.—No. 12
—— see Alvarez, L. W.
Corson, Dale R. and Kenneth R. MacKenzie—No. 15

Dancoff, S. M.—No. 21
Dibble, Barry—see Strong, John

Fitzsimmons, K. E.—No. 23
Fowler, Charles A., Jr. and F. A. Jenkins—No. 3

Gast, Paul—see Loughridge, Donald H.
Givens, J. W., O. Beeck and E. C. Williams—No. 4
—— see Beeck, O.

Haseltine, William R.—No. 33
Helmholz, A. C.—No. 9

Jenkins, F. A. and R. E. Worley—No. 28
—— see Fowler, Charles A., Jr.

Kaplan, J.—No. 13
Kruger, P. Gerald—No. 16
Kyropoulos, S.—No. 6

Leonard, Robert W.—No. 32
Loughridge, Donald H. and Paul Gast—No. 11

MacKenzie, Kenneth R.—see Corson, Dale R.
Meek, J. M.—No. 1
Morrison, P.—see Cooper, E. P.
Mrozowski, S.—Nos. 29 and 34

Nelson, Eldred—No. 27
Nelson, Martin E. and Stanley S. Ballard—No. 30

Schiff, L. I.—No. 19
Schuchard, E. A.—see Uehling, E. A.
Slepian, Joseph and W. M. Brubaker—No. 18
Smith, A. E.—see Beeck, O.
Snyder, H. and J. Weinberg—No. 20
Strong, John and Barry Dibble—No. 2
Sumerlin, W. T.—see Bradbury, N. E.

Uehling, E. A. and E. A. Schuchard—No. 24

Volkoff, G. M.—No. 25

Waithman, V. B. and W. R. Baker—No. 26
Weinberg, J.—see Snyder, H.
Weissler, Gerhard L.—No. 31
Weller, R.—No. 22
Williams, E. C.—see Givens, J. W.
Worley, R. E.—see Jenkins, F. A.